LONG-TERM EXPERIMENTS AT CBARC-PENDLETON, 2004

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Abstract

The Columbia Basin Agricultural Research Center (CBARC) is home to the oldest experiments in the Pacific Northwest (PNW). The perennial grassland, conventional-till continuous cereal, and crop residue management experiments were initiated in 1931, and the tillage-fertility, wheat-pea rotation experiments were initiated in 1940 and 1963. In 1998, a no-till continuous cereal was added to mirror the conventional-till continuous cereal. This article summarizes the results obtained in 2004. The *perennial grassland* serves as a baseline for comparisons with other systems. *Continuous cereal*: in both conventional and no-till cropping systems, spring barley produced the highest yield, followed by winter wheat and then spring wheat. Winter wheat, spring barley, and spring wheat produced higher yields under conventional tillage than under the no-till cropping system. *Crop residue*: highest yields were obtained when manure was applied, followed by 80-lb nitrogen (N) rates. Treatments involving field burning without N application and check treatments resulted in the lowest yields. *Wheat-pea rotation*: for wheat, highest yields were produced under no-till management. Spring plow, fall plow, and fall chisel treatments all had lower yields. For peas, highest yields were produced in the no-till and spring plow treatments. Fall plow and fall disk treatments had lower yields. *Tillage fertility*: tillage fertility plots were in fallow during 2004. *Continuous no-till winter wheat (USDA):* yields and test weights continue to be collected on this trial with a 7-year average yield of 70.9 bu/acre.

Key Words

Carbon sequestration, cropping systems, organic matter

Introduction

Long-term research guides future agricultural development by identifying the effects of crop rotation, variety development, fertilizer use, aerial and surface contamination, and organic amendments on soil productivity and other beneficial soil properties. Comprehension and evaluation of many changes often require 10-20 years to identify and quantify. Soil microflora and soil-borne plant pathogens require from 2 to 8 years in a new cropping sequence or tillage system to reach a stable equilibrium. To this end, long-term experimentation is required to understand interactions among soil, water, and plant factors for both agronomic and agricultural policy decisions. The oldest experiments in the PNW are at CBARC, Pendleton, in the intermediate rainfall zone (Table 1). Below is a brief description of these experiments and the results obtained in the 2004 crop year. The treatments have changed over the years and the descriptions below refer to current procedures. Detailed descriptions of the protocols and how they have changed over time have been compiled into a database located on our network server.

Description of Experiments

Table 1. Long-term experiments at Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Experiment	Treatments	Year initiated
Perennial grassland	None	1931
Conventional-till continuous cereal	Fertility, tillage	1931
Residue management	N, manure, burning, pea vine	1931
Tillage-fertility	Tillage, fertility	1940
Wheat-pea	Tillage, fertility	1963
No-till continuous cereal	Fertility, tillage	1998
Continuous no-till winter wheat (USDA)	None	1998

Perennial grassland

The perennial grassland site (150 ft wide by 360 ft long) contains no experimental variables but has been maintained since 1931. The site is intended to approximate a near-virgin grassland and serves as a baseline for evaluating changes in other cropping systems. It is periodically reseeded with introduced grass selections, occasionally fertilized, and infrequently irrigated. The dominant grass species are bluebunch wheatgrass (*Agropyron spicatum var. 'Secar'*) with lesser amounts of Idaho fescue (*Festuca idahoensis var. 'Joseph'*). Weeds, particularly witchgrass (*{Panicum capillare*), common mallow (*Malva neglecta*), and downy brome (*Bromus tectorum*), are controlled as needed. In 2004, prickly lettuce (*Lactuca serriala*) made an appearance in areas where the grass stand was thin. This stand was renovated and reseeded during 2002 and 2003. Broadleaf weeds were controlled in 2003 and 2004 with broadcast applications of dicamba/carfentrazone-ethyl and 2,4-D amine/MCPP mixtures and spot applications of MCPA. This site received limited grazing from 1931 to 1985. It has not been grazed since but vegetation is sometimes clipped during or after summer growth. Above-ground productivity was measured in 2004 for the first time since renovation. Species counts were initiated in 2004. A 10-year comprehensive soil sampling was begun in 2004.

Continuous cereal

The objectives of the various continuous cereal monocultures have varied over the years; however, the current objective is to determine the effects of annual mono-cropping on crop yield and soil productivity. Annual monoculture plots of winter and spring wheat and spring barley, using plow (inversion) tillage are maintained. In each plot there are fertilized and unfertilized blocks. Treatment histories for the tilled plots are shown in Table 2. A no-till (direct seeded) annual winter and spring wheat and spring barley companion plot was established in 1998 and the treatments are shown in Table 3. The plots are not replicated. The most practical, generally recommended methods and equipment available to growers are used. In 2004, a John Deere (JD) 8300 double disk drill on 6.8-inch spacing was used to seed all conventional-till monocultures. In 2004 a JD 1560 disk drill on 7.5-inch spacing was used to seed no-till spring barley and no-till spring wheat monocultures. A Conservapak (CP) hoe drill on 12-inch spacing was used to seed the no-till winter wheat monoculture. Spring barley plots were seeded to

'Baronesse', spring wheat plots were seeded to 'Zak', and winter wheat plots were seeded to 'Stephens'. Target seeding rates are contained in Table 4. All fertilized mono-cultures received the equivalent of 100 lbs/acre of 16-20-0-14 (nitrogen [N], phosphorus [P], potassium [K], sulfur [S]). In conventional-till spring plots this was applied as a plowdown dry product. In conventional-till winter wheat plots this was shank-applied after plowing. In no-till monocultures this was drill-applied at seeding either as a liquid or a dry product. In conventional-till spring plots the balance of the N was applied as plowdown urea granules. In the conventional-till winter wheat monoculture the balance of the N was shank-applied after plowing as urea ammonium nitrate solution. In no-till monocultures the balance of the N was drill-applied as urea granules in the no-till winter wheat plot or as urea ammonium nitrate solution in the spring no-till monocultures. Glyphosate was applied to all monocultures before sowing or plowing. Bromoxynil was used to control broadleaf weeds in the winter wheat no-till monoculture. Bromoxynil and MCPA ester was used to control broadleaf weeds in all other monocultures. Downy brome was controlled in the conventional-till winter wheat monoculture with preplant incorporated diclofop-methyl and pre-emergence metribuzin applications. Downy brome was controlled in the no-till winter wheat monoculture with a preplant application of triallate and a preemergence application of metribuzin. Except for the conventionally tilled spring-sown mono-cultures, all unfertilized components of the other monocultures required a post-harvest treatment with glyphosate for post-harvest broadleaf control. Post-harvest treatment was not required in any of the fertilized components of this experiment.

Table 2. Treatment history of the tilled continuous cereal monocultures, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Period	Crop grown	Variables	N application
1932-1950	Winter wheat	Fertilizer rate and type	0-126
1951-1958	Winter wheat	None	0
1959-1976	Winter wheat	None	70
1977-1992	Winter wheat	None	80
1993-present	Winter wheat	Fertility	0,80
1932-1953	Spring wheat	Fertilizer rate and type	0-94
1954-1958	Spring wheat	None	0
1959-1976	Spring wheat	None	74
1977-1992	Spring wheat	None	80
1993-present	Spring wheat	Fertility	0,80
1982-1994	Spring barley	None	80
1994-present	Spring barley	Fertility	0,80

Table 3. Treatment history of the direct-seeded continuous cereal monocultures, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Period	Crop grown	Variable	N application
1998-present	Spring barley	N rate	0,90
1998-present	Spring wheat	N rate	0,90
1998-present	Winter wheat	N rate	0,100

Table 4. Target seeding rates and stand for fertilized continuous cereal monocultures, Columbia Basin Agricultural Research Center, Pendleton, Oregon, 2004.

Crop grown	System	Target seeding rate (seeds/ft^2)	Stand (plants/ ft^2)
Winter wheat	Conventional till	22	16
Winter wheat	No till	25	13
Spring barley	Conventional till	23	16
Spring barley	No till	26	22
Spring wheat	Conventional till	26	22
Spring wheat	No till	29	25

Table 5. Treatment history of the residue management (CR) experiment, Columbia Basin Agricultural Research Center, Pendleton, Oregon..

		1931-1966		1967-1978		1979 to present	
Trt No.	Organic N addition	RT[a]	N[b]	RT	N	RT	N
1	---[c]	--	--	--	--	--	--
2	---	FD	0	NB	40	SB	40
3	---	SD	0	NB	80	SB	80
4	---	NB	30	NB	40	NB	40
5	---	NB	30	NB	80	NB	80
6	---	FB	0	FB	0	FB	0
7	---	SB	0	SB	0	SB	0
8	Manure[d]	NB	0	NB	0	NB	0
9	Pea vines[e]	NB	0	NB	0	NB	0
10	---	NB	0	NB	0	NB	0

[a] Residue treatment: FD = fall disk, SD = spring disk, NB = no burn, FB = fall burn, SB = spring burn.
[b] N rate (lb/acre/crop); applied early October of crop year.
[c] 1 ton/acre/crop field weight alfalfa hay applied to plot 11 1939-1949 1-3 days prior to plowing.
[d] Manure = 10 tons/acre/crop wet weight; 47.5 percent dry matter; 1,404 lb C and 113 lb N/acre/crop; applied in April or May of plow year (1-3 days prior to plowing).
[e] Pea vines = 1 ton/acre/crop field weight; 88.4 percent dry matter; 733 lb C and 34 lb N/acre/crop; applied 1-3 days prior to plowing.

Crop residue management

The crop residue experiment is the most comprehensive of the long-term experiments at Pendleton. The objective of the experiment is to determine the effects of N application, burning, and pea vine and manure application on soil properties and productivity in a conventional moldboard plow, winter wheat-summer fallow production system. Treatment history is shown in Table 5. The experimental design is an ordered block consisting of 9 treatments (10 originally) and 2 replications. The experiment contains duplicate sets of treatments that are offset by 1 year so that data can be obtained annually. In 2004, plots were seeded to 'Stephens' using a JD 8300 double disk drill on 6.8-inch spacing. The target sowing rate was 22 seeds/ft^2.

Glyphosate was applied before plowing in the spring of 2003. Broadleaf weeds were controlled with bromoxynil and MCPA ester in the spring of 2004.

Tillage fertility

The objective of the tillage fertility experiment is to determine the effects of three tillage regimes and six N rates on soil properties and productivity in a tilled winter wheat-summer fallow production system. Treatments are shown in Table 6. The experimental design is a randomized block split-plot with three replications. Main plots consist of three primary tillage systems (moldboard plow, offset disk, and subsurface sweep) and subplots of six fertility levels. These plots were in fallow during 2004.

Table 6. Treatment history of the tillage-fertility (TF) experiment, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Primary treatment (tillage)		Tillage depth	Average residue cover
Symbol	Type	(inches)	at seeding (%)
MP	Moldboard plow	9	7
DI	Offset disk	6	34
SW	Subsurface Sweep	6	43

Subtreatment (fertility)		N rate (lb/acre/crop)[a]			
No.	Sulfur application	1941-1952	1953-1962	1963-1988	1989-present
1	No	0	0	40	0
2	Yes	10	30	40	40
3	No	0	0	80	80
4	Yes	10	30	80	80
5	Yes	10	30	120	120
6	Yes	10	30	160	160

[a]N applied 7-14 days prior to seeding as ammonium sulfate from 1941 to 1962, ammonium nitrate from 1963 to 1988, and urea-ammonium nitrate since 1989. N was broadcast from 1941 to 1988, and banded 6 inches deep with 12-inch row spacing since 1989.

Wheat/pea

The wheat/pea experiment was established in 1963. The objective of the experiment is to determine effects of four different tillage regimes on soils properties and productivity in a wheat/legume annual crop rotation. Treatments are shown in Table 7. Crop rotation is winter wheat/dry spring pea and the experimental design is a randomized block with four replications. Each replication contains eight plots (four treatments duplicated within each replication). Duplicate treatments, offset by 1 year, ensure yearly data collection for both wheat and peas. In 2004, all tilled plots were seeded using a JD 8300 double disk drill on 6.8-inch spacing. In 2004 no-till pea plots were sown with a JD 1560 drill on 7.5-inch spacing and no-till wheat plots were sown with a Great Plains double disk drill on 10-inch spacing. Target sowing rates were 22 seeds/ft^2 for winter wheat and 8 seeds/ft^2 for spring pea. ‘Stephens’ winter wheat and ‘Universal’ dry yellow pea were sown in 2004. All fertilizer was applied as preplant shank-applied liquid fertilizer. Tilled winter wheat plots received 80 lb N/acre and no-till winter wheat plots received 90 lb N/acre. All pea plots received 16 lb N/acre. Both peas and wheat received P and S along with the N application. Glyphosate was applied to both peas and wheat before sowing or tillage. Downy brome was controlled in the no-till wheat plots with a preplant application of triallate. This was followed with a spring postemergence application of metribuzin coupled with a bromoxynil treatment to control broadleaf weeds. Conventional-till wheat plots had a preemergence application of metribuzin to control downy brome and a spring application of bromoxynil and MCPA to control broadleaf weeds. Peas received a postplant incorporated application of metribuzin and imazethapyr for broadleaf control.

Continuous no-till winter wheat (USDA)

These plots were established as no-till in the fall of 1997. Prior to that year the plots were planted to conventionally tilled winter wheat each fall since 1931. Crop years 1998 and 1999 included two no-till drill treatments in addition to different fertilizer types, rates, and placement. From crop year 2000 to present, the drill used, fertilizer regime, and seeding rate have been relatively unchanged. A preseeding application of Round-up Ultra® (glyphosate) is made each fall at a rate of 24 oz/acre. The Conservapak drill is used to seed ‘Stephens’ winter wheat in mid- to late October at a target rate of 25 seeds/ft^2 or approximately 100 lb/acre. At seeding, the Conservapak delivers all fertilizer down the fertilizer shank below and to the side of the seed at rates of 105 lb/acre of 16-20-0 and 185 lb/acre of 46-0-0. A broadleaf herbicide application is made in the spring using Banvel® (dicamba) at 4 oz/acre and Bronate® (Bromoxynil plus MCPA ester) at 1.5 pt/acre. Clarity® (Dicamba) plus Salvo® (isooctyl ester of 2,4-D) was applied in April 2001. Flailing of standing stubble is done after harvest.

Table 7. Current treatments of the wheat/pea (WP) experiment, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Treatment		Primary tillage	
No.	Identification	Wheat stubble	Pea vines
1	Max till	Disk (fall)	Chisel (fall)
2	Fall plow	Plow (fall)	Plow (fall)
3	Spring plow	Plow (spring)	Plow (fall)
4	No till	No till	No till

Efforts are being made to control cheatgrass using herbicides and changing varieties but cheatgrass is still a major problem in this experiment. Maverick® (Sulfosulfuron) was applied in March 1999. Fargo® (Triallate) was incorporated at seeding in October 2001. A Clearfield® wheat variety was planted in October 2002, with Beyond® (Imazamox) applied in March 2003. Maverick was applied again in March 2005. Hand weeding of goatgrass has been effective.

Results and Discussion

Precipitation and temperature

The Pendleton station received 118 percent of the 74-year average crop-year precipitation in 2004 (Table 8). Winter precipitation amounted to 114 percent of the 74-year average winter precipitation and spring precipitation was 126 percent of the 74-year average spring precipitation. Only the months of September, October, and November of 2003 and March of 2004 had below-average precipitation. Based on growing degree days (GDD), the crop-year, winter, and spring temperatures were slightly warmer than the 74-year average (Table 8). Only the months of November 2003 and January 2004 had below-normal temperature averages.

Managed perennial grassland

This perennial grassland serves as a baseline for comparisons with other systems. Usually scientists sample the area to obtain data to answer specific questions they are investigating at other sites. Above-ground biomass was measured for the first time since 1996. Species counts were done in the spring of 2004. A comprehensive 10-year sampling was done in 2004 to determine carbon status and other characteristics of this area.

Continuous cereal

Plant stand

In both conventional and no-till winter wheat plots, plant stands in the fertilized portion of each monoculture were equal to those of the unfertilized portion. Stands of all monocultures except for the no-till winter wheat monoculture equaled 71 to 86 percent of targeted sowing rates (Table 4).

Table 8. Precipitation and growing degree days (GDD) in the 2004 crop-year, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

	2004	74-year average
Fallow year precipitation (in)	15.65 (2003)	16.46
Crop-year precipitation (in) Sept 1-June 30	18.63	15.67
Two-year precipitation (in)	34.28 (2003-2004)	32.13
Winter season precipitation (in) Sept 1-Feb 28	11.09	9.71
Spring season precipitation (in) March 1-June 30	7.54	5.96
Crop-year GDD Sept 1-June 30	2,788.9	2,641.9
Winter season GDD Sept 1-Feb 28	1,287.8	1,230.0
Spring season GDD March 1-June 30	1,501.1	1,411.8

The stand in the no-till winter wheat monoculture was only 52 percent of the targeted sowing rate. In general, precipitation and temperatures were adequate in the fall of 2003 and the spring of 2004 to achieve adequate stands under most conditions. Percent residue cover, measured with a line-transect method, varied from 91 to 100 percent for all no-till monocultures and from 36 to 85 percent for all conventional-till monocultures.

Grain yield and yield components and other measurements

The continuous cereal cropping systems plots are not replicated and therefore combine yield cannot be statistically compared. However, it is statistically acceptable to compare the systems through t-tests conducted on four bundle samples obtained from each monoculture. Bundle grain yields were highly correlated to combine grain yields ($r = 0.95$, $P < 0.01$). Combine yields will be discussed in this paper. For brevity, only significant tests for combine grain yield will be shown (Table 10). In 2004 downy brome did not affect yield in any of the winter-sown monocultures (Table 9). Stripe rust (*Puccinia striiformis*) seriously affected all spring wheat monocultures that were sown to the variety ‘Zak’. On June 18, 2004, 30 percent of the flag leaves had greater than 5 percent of their surface area covered. At this time the variety had 50 percent of its heads fully emerged from the boot. The extent of yield loss from stripe rust is not known. Other variables that were measured were combine grain yield, bundle grain yield, test weight, kernel weight, harvest index, percent protein, heads/ft^2, spikelets/head, and kernels/head.

Fertility effects

For all monocultures, fertilized plots produced significantly higher grain yields than unfertilized plots (Tables 9 and 10). Combined data indicate that unfertilized plots yielded 55 percent of fertilized plots. Fertilizer application in no-till winter wheat and no-till spring barley monocultures did not significantly affect test weight. Both in the no-till and conventional-till treatments of spring wheat and conventional-till spring barley monocultures, test weights were significantly reduced by fertilization. Fertilization with N significantly increased test weight in the conventionally tilled winter wheat monocultures. Kernel weights were significantly decreased by fertilizer application in all spring and winter wheat monocultures. In spring barley monocultures, kernel weight was increased by fertilization. Nitrogen fertilizer significantly increased percent protein in all monocultures. In no-till spring barley and spring wheat monocultures, fertilization increased the average percent protein by 2.9 percent. The number of heads/ft^2 was significantly increased by fertilization. The number of heads/ft^2 in unfertilized monocultures was about 61 percent of the heads/ft^2 in fertilized monocultures. Spikelets/head were significantly increased by fertilization in the conventional till spring wheat monoculture and the no-till winter wheat monoculture. Kernels/head were not significantly affected by fertilizer.

Conventional tillage

The t-test results for combine grain yield (Table 9) are shown in Table 10. Conventionally tilled fertilized winter wheat and spring barley yielded significantly more than spring wheat (Tables 9 and 10). Spring barley yields were not significantly different from winter wheat. Among the conventionally tilled unfertilized plots, spring barley produced significantly more grain yield than winter wheat and spring wheat. There was no significant difference in grain yield between unfertilized winter wheat and unfertilized spring wheat. High yield in unfertilized and fertilized spring barley was attributed to high numbers of heads/ft^2 and spikelets/head. Among the conventionally tilled fertilized plots, winter wheat produced significantly higher grain protein than spring wheat and spring barley. Among the conventionally tilled unfertilized plots, winter wheat produced significantly higher grain protein than spring barley but this was not significantly different from spring wheat grain protein.

No-till

The t-test results for combine grain yield (Table 9) are shown in Table 10. Among no-till fertilized monocultures, spring barley produced significantly higher yields than winter wheat and spring wheat. Winter wheat yields were significantly higher than spring wheat (Tables 9 and 10). Among no-till unfertilized monocultures, spring barley yields were significantly higher than spring wheat yields and spring wheat yields were significantly higher than winter wheat yields. High yield in unfertilized and fertilized spring barley was attributed to high numbers of heads/ft^2, spikelets/head, and kernel weight. Among no-till unfertilized monocultures, winter wheat had significantly higher grain protein than spring wheat and spring barley.

Conventional tillage v. no-till

Under both fertilized and unfertilized situations, conventional-till winter wheat yielded significantly more than no-till winter wheat. High yield in conventional-till winter wheat was attributed to high kernel weight and kernels/head in fertilized crops and to high kernel weight, heads/ft^2, spikelets/head and kernels/head in unfertilized plots (Table 9). Conventional-till spring wheat yielded significantly more than no-till spring wheat under fertilized conditions. No significant differences in yield were observed between unfertilized conventional-till and no-till spring wheat. High yield in conventional-till spring wheat was attributed to high kernel weight, spikelets/head, and kernels/head. There were no significant differences in yields of no-till spring barley and conventional-till spring barley under fertilized conditions but the no-till spring barley yielded significantly less than unfertilized conventional-till spring barley. High yield in unfertilized conventional-till spring barley was attributed to high kernel weight, heads/ft^2, and spikelets/head.

Crop residue management

Crop residue plots were seeded at a target rate of 22 seeds/ft^2. Treatment had no significant effect on resulting stand, which varied from 68 to 82 percent of target plants (Table 11). No downy brome was present in these plots and surface residue after seeding was insignificant. Combine grain yield and bundle grain yield were highly correlated ($r = 0.91$, $P < 0.0001$) and treatment significantly affected grain yield. Manure plots had the highest yields, followed by N treatments, spring burn N and pea vine treatments, and check; spring and fall burn treatments had the lowest yield. Both burn treatments yielded significantly less than treatment 1 (check). The yield of the 80-lb N spring burn treatment was significantly higher than the 40-lb N spring burn treatment. Grain yield was significantly correlated with plant stand ($r = -0.34$, $P < 0.05$), heads/ft^2 ($r = 0.61$, $P < 0.0001$), harvest index ($r = 0.73$, $P < 0.0001$), and grain protein ($r = 0.80$, $P < 0.0001$). Grain protein content was significantly affected by treatment and ranged from 6.5 percent in the fall burn treatment to 9.8 percent in the unburnt 80-lb fertilized treatment. Spring burning did not significantly reduce grain protein content. Grain protein content in manure plots was intermediate between 80-lb fertilized treatments and 40-lb fertilized treatments. The grain protein content of pea vine plots was similar to 40-lb fertilized treatments. Check plots had grain protein content significantly higher than both burn treatments.

Table 9. Comparisons of no-till and conventional-till monocultures with and without nitrogen (N) fertilizer, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

	CTCWW[a]		CTCSW		CTCSB		NTCWW		NTCSW		NTCSB	
N fertilizer	+ N	- N	+ N	- N	+ N	- N	+ N	- N	+ N	- N	+ N	- N
Stand count plants/ft^2	16.3	19.9	21.9	21.4	16.4	17.3	13.0	10.8	24.9	25.6	22.3	20.8
Combine yield bu/acre	85.0	35.7	62.4	41.5	104.7	60.4	68.4	24.6	46.2	40.2	106.4	44.8
Bundle yield bu/acre	95.4	60.8	66.0	48.9	103.1	65.8	76.5	31.7	49.9	43.7	112.8	59.8
Test weight lb/bu	58.5	59.1	57.2	60.3	53.8	53.0	57.5	58.8	53.1	59.5	52.6	52.1
1,000-kernel weight combine grain oz	1.63	1.85	1.11	1.51	1.51	1.44	1.40	1.67	0.78	1.43	1.44	1.38
1,000-kernel weight bundle grain oz	1.75	1.53	1.19	1.51	1.52	1.41	1.48	1.64	0.87	1.43	1.41	1.42
Percent grain protein	9.9	8.6	9.6	8.5	9.3	8.2	10.0	8.9	10.6	7.9	11.0	7.9
Harvest index	0.40	0.43	0.37	0.42	0.45	0.30	0.40	0.40	0.29	0.38	0.43	0.48
Heads/ft^2	44.2	30.4	45.1	28.4	65.7	46.9	43.3	24.7	55.8	31.7	85.1	44.2
Spikelets/head	15.2	17.2	16.7	14.2	21.2	20.8	15.7	14.1	15.7	12.9	20.4	18.8
Kernels/head	37.9	38.5	30.6	28.9	18.3	17.7	33.8	31.9	27.8	24.3	19.0	16.6
Downy brome plants/ft^2	0.2	0.4	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Percent residue at seeding	36	44	85	46	39	25	100	100	95	93	99	91

[a]CTCWW: conventional-tillage continuous winter wheat.
CTCSW: conventional-tillage continuous spring wheat.
CTCSB: conventional-tillage continuous spring barley.
NTCWW: no-tillage continuous winter wheat.
NTCSW: no-tillage continuous spring wheat.
NTCSB: no-tillage continuous spring barley.

Table 10. T-test comparisons of mean bundle yield under different continuous cereal cropping systems in 2004 (Pr > t), Columbia Basin Agricultural Research Center, Pendleton, Oregon.

	ctcwwf[a]	ctcswf	ctcsbf	ctcwwnf	ctcswnf	ctcsbnf	ntcwwf	ntcswf	ntcsbf	ntcwwnf	ntcswnf
ctcswf	***[b]										
ctcsbf	ns[c]	**									
ctcwwnf	**	**	***								
ctcswnf	***	**	***	ns							
ctcsbnf	***	**	***	*	*						
ntcwwf	**	ns	**	**	****	**					
ntcswf	****	**	***	ns	ns	ns	***				
ntcsbf	ns	**	ns	****	**	**	*	**			
ntcwwn f	****	****	****	*	*	**	***	**	****		
ntcswnf	****	**	****	ns	ns	*	****	**	**	**	
ntcsbnf	****s	**	****	ns	*	**	****	**	**	*	*

[a]ctcwwf – conventional tillage, continuous winter wheat, fertilized.
ctcswf– conventional tillage, continuous spring wheat, fertilized.
ctcsbf– conventional tillage, continuous spring barley, fertilized.
ctcwwnf – conventional tillage, continuous winter wheat, no fertilizer.
ctcswnf– conventional tillage, continuous spring wheat, no fertilizer.
ctcsbnf– conventional tillage, continuous spring barley, no fertilizer.
ntcwwf – no tillage, continuous winter wheat, fertilized.
ntcswf – no tillage, continuous spring wheat, fertilized.
ntcsbf – no tillage, continuous spring barley, fertilized.
ntcwwnf – no tillage, continuous winter wheat, no fertilizer.
ntcswnf – no tillage, continuous spring wheat, no fertilizer.
ntcsbnf – no tillage, continuous spring barley, no fertilizer.

[b]*, **, ***, and ****: means significantly different at the 0.05, 0.01, 0.001, and 0.0001 levels of probability.

[c]ns–means not significantly different.

Table 11. Crop residue data for 2004, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

	Check 1	Check 10	Spring burn 40 lb N/acre	Spring burn 80 lb N/acre	40 lb N/acre	80 lb N/acre	Fall burn	Spring burn	Manure	Pea vine
Treatment	1	10	2	3	4	5	6	7	8	9
Stand count plants/ft^2	18.6a[a]	17.0a	15.7a	15.6a	17.4a	15.1a	17.0a	18.6a	16.1a	17.0a
Combine yield bu/acre	58.0e	49.6f	71.2d	80.4c	82.6bc	88.5b	43.4f	46.0f	108.4a	79.7c
Bundle yield bu/acre	56.2d	51.8d	74.3c	91.3b	87.5b	82.4bc	48.4d	50.4d	109.4a	73.2c
Test weight lb/bu	58.7e	58.6	59.9cd	61.0a	60.2c	60.9ab	58.2f	58.8e	60.6b	59.8d
1,000-kernel weight combine grain oz	1.80e	1.84de	1.85cde	1.89abcd	1.89abc	1.92ab	1.82e	1.84cde	1.94a	1.86bcde
1,000-kernel weight bundle grain oz	1.86de	1.81e	1.91bcd	1.97abc	1.82bcd	1.98ab	1.86de	1.86de	2.02a	1.88cde
Percent grain protein	7.1ef	7.3e	8.4cd	9.6a	8.8bc	9.8a	6.5g	6.8fg	9.0b	7.9d
Harvest index	0.37c	0.36cd	0.39b	0.41ab	0.39b	0.42a	0.35d	0.36cd	0.43a	0.39b
Heads/ft^2	29.1c	31.0bc	32.5abc	38.3ab	37.4ab	33.8abc	27.4c	26.6c	40.0a	33.6abc
Spikelets/head	14.5ab	15.0ab	13.5b	14.2ab	13.8b	14.0ab	15.8a	15.0ab	15.8a	15.8a
Kernels/head	28.4a	30.5a	27.1a	30.4a	28.3a	31.8a	29.0a	34.4	36.9a	37.2a

[a] Means with the same letters are not significantly different at the 0.05 probability level.

Wheat/pea

Pea

In 2004 peas were seeded at a target rate of 8 seeds/ft^2. Stands were unaffected by treatment and ranged from 8.4 to 10.1 plants/ft^2 (Table 12). No downy brome was present in these plots. Combine and bundle yields were poorly correlated (r = 0.16). To this end, bundle yields, of which we are confident, are discussed below. No-till and spring plow treatments produced significantly higher yields than fall plow and disk treatments (Table 12). Standing stubble left over winter may have contributed to increased water storage over winter. High yields were significantly correlated with 1,000 kernel weight (r = 0.50, $P < 0.01$) and harvest index (r = 0.44, $P < 0.01$).

Wheat

Combine and bundle yields were poorly correlated (r = -0.01). To this end, bundle yields, of which we are confident, are discussed below. Wheat was seeded at a target rate of 22 seeds/ft^2 for tilled systems and 25 seeds/ft^2 for the no-till system. The chisel-after-pea treatment had significantly more plants/ft^2 than the no-till treatment (Table 12). However, plant stands were not significantly different between chisel-after-peas, spring plow, and fall plow treatments. Residue levels (determined by line transect method) that ranged from 100 percent for the no-till treatment to 20.5 percent for the spring plow treatment probably interfered with plant emergence under no-till. The reduction in plant stand, however, did not affect yields; there were no significant differences in grain yield between the treatments. There were no clear associations between grain and the yield components. Grain yields were not affected by downy brome infestation, although the number of brome plants was significantly higher in no-till than in other treatments. Fall plow and chisel treatments had significantly higher grain protein than spring plow and no-till treatments.

Insert table 12

Tillage fertility

Data from the tillage fertility experiment were obtained in alternate years. No data are available as plots were in fallow in 2004.

Continuous no-till winter wheat (USDA)

Yield and test weight data from 1998 to 2004 are shown in Table 13. Grain yield was positively correlated with spring precipitation (r = 0.86, $P < 0.05$).

Table 13. Yields and test weights of continuous no-till winter wheat trial (USDA), Columbia Basin Agricultural Research Center, Pendleton, Oregon, 1998-2004.

	Crop year						
	1998	1999	2000	2001	2002	2003[a]	2004
Planting date	Oct 24	Oct 15	Oct 15	Oct 18	Oct 25	Oct 28	Oct 27
Test weight (lb/bu)	60.0	59.9	61.0	58.5	56.5	57.2	55.7
Combine yield (bu/acre)	82.0	65.8	84.3	65.2	55.0	61.3	82.5
Crop-year precipitation (in)	15.0	16.9	18.7	15.7	12.6	15.2	15.0
Winter precipitation (in)	8.8	12.4	11.4	10.1	7.8	10.3	8.8
Spring precipitation (in)	6.3	4.4	7.3	5.7	4.9	4.9	6.3

[a] Clearfield winter wheat.